# Deep Ocean Standards Thermometer

# SBE 35

The SBE 35 is a laboratory standards thermometer with the unique ability to be used both in fixed point cells and at depths up to 6800 meters. It is unaffected by shock and vibration encountered in shipboard and industrial environments, making it ideal for use in calibration laboratories in the range of -5 to +35° C, and in the thermodynamic method of measuring hydro turbine efficiency.

**DEEP OCEAN APPLICATIONS**

The SBE 35 is designed to operate with an SBE 9*plus* CTD / SBE 32 Carousel Water Sampler system, and records a temperature measurement in EEPROM each time the water sampler closes a bottle. Each record also contains the bottle position and a time stamp to coordinate the thermometer data with CTD and water bottle data. Using one SBE 35 eliminates the need for reversing thermometers, and provides higher accuracy temperature readings at lower cost.

**INDUSTRIAL OR LABORATORY APPLICATIONS**

The thermometer's digital output can be displayed in real-time and logged to disk using an IBM compatible PC. The SBE 35 is standardized in water triple point (TPW) and gallium melting point (GaMP) cells following the methodology applied to a standards-grade platinum resistance thermometer (SPRT). But unlike SPRTs, it does not require an expensive resistance bridge, making the SBE 35 a dramatically cost-effective alternative. For measurements in fixed point cells, the protective guard is removed and a brass and plastic tip bushing is attached to give the SBE 35 a length, diameter, and thermal averaging characteristic of an SPRT. The SBE 35 resolves temperature in fixed point cells to approximately 0.000025° C (25 µK) (see figure 1). Accuracy is better than 1 mK.

**MEASUREMENT METHOD**

Temperature is determined by applying an AC excitation to reference resistances and an ultrastable aged thermistor with a drift rate of less than 0.001°C per year. Each of the resulting outputs is digitized by a 20-bit A/D converter. The reference resistor is a hermetically-sealed, temperature-controlled VISHAY. The switches are mercury wetted reed relays with a stable contact resistance. AC excitation and ratiometric comparison using a common processing channel removes measurement errors due to parasitic thermocouples, offset voltages, leakage currents, and gain errors. Maximum power dissipated in the thermistor is 0.5 microwatts, and contributes less than 200 µK of overheat error. The output from the sensor is a raw count related to resistance measurements as:

**1048576 * (NT - NZ) / (NR - NZ)**

where NR is the output from the reference resistor, NZ is the output from zero ohms, and NT is the thermistor output.

Each measurement acquisition cycle takes 1.1 second. The number of acquisition cycles per measurement is programmable. Increasing the number of cycles per measurement increases the time to acquire the sample while reducing the RMS temperature noise from the sensor. In a thermally quiet environment, the temperature noise standard deviation is 82 * sqrt (1/n cycles) [µK].

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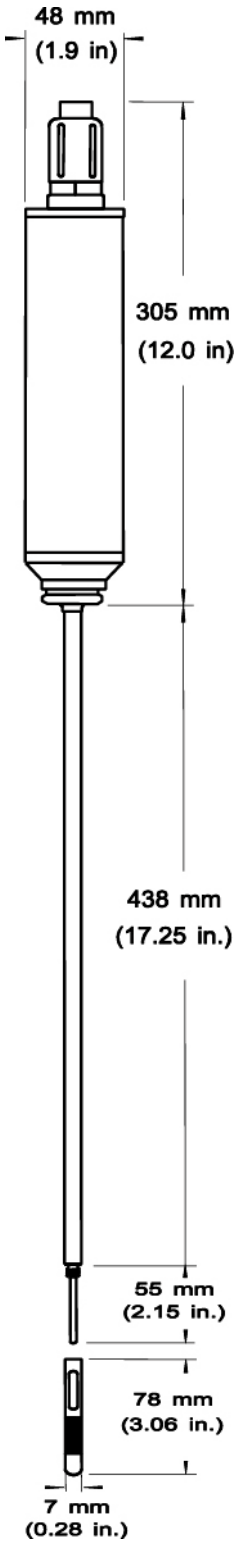



**POWER AND RS-232 SERIAL INTERFACE**

The thermometer is supplied with a small desktop interface box that is connected between the SBE 35 and a PC and is required for setup and data display or retrieval. The interface box is 110/220 VAC powered, provides 15 VDC to the SBE 35, and buffers the communication lines to minimize interference from external noise.

**SOFTWARE**

IBM-PC compatible programs are supplied with the SBE 35 to handle communication and setup, real-time data display, data retrieval, conversion from counts to temperature, computing average and standard deviation, and hard copy printing.

**LINEARIZATION AND CALIBRATION**

Following the methodology used for SPRTs, the calibration of the SBE 35 is accomplished in two steps. The first step (A) is to characterize the non-linear temperature vs resistance response of the sensor. Temperature is computed using the Steinhart-Hart polynomial for thermistors (Steinhart and Hart, 1968; Bennett, 1972) which is based on thermistor physics (n is the SBE 35 output):

$$\text{(A)} \qquad t_{90L} = \frac{1.0}{a0 + a1\ln(n) + a2\ln^2(n) + a3\ln^3(n) + a4\ln^4(n)} - 273.15$$

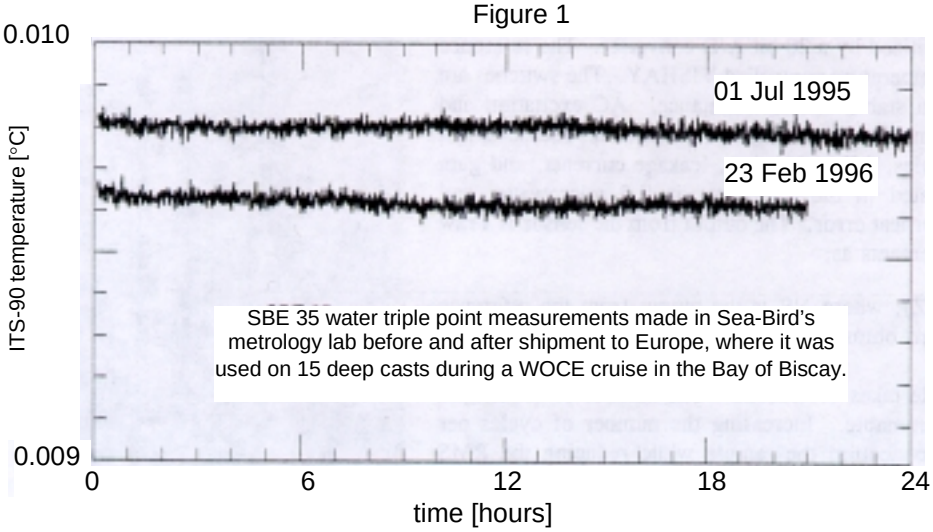
$$\text{(B)} \qquad t_{90L} = slope \times t_{90L} + offset \quad [\text{deg C, } ITS\text{-90}]$$

Carried to fourth order, this equation characterizes the SBE 35 output to an error of ± 50 µK.

Unlike SPRTs where the basic non-linear calibration equation has fixed coefficients that apply to pure platinum, thermistors require individualized coefficients to the Steinhart-Hart equation because the thermistor material is an individualized mix of dopants. The individualized SBE 35 calibrations are performed at Sea-Bird in a low-gradient temperature bath and against ITS-90 certified SPRTs maintained at Sea-Bird's primary temperature metrology laboratory.

The second step (B) is certification of the sensor by measurements in thermodynamic fixed point cells. The water triple point (0.0100 °C) and gallium melt point (29.7646 °C) are used because the SBE 35 is designed for ocean range temperatures (-5 to 35 °C). Like SPRTs, the slow time drift of the SBE 35 is adjusted by periodic recertification corrections (equation B).

Figure 1




SBE 35 water triple point measurements made in Sea-Bird's metrology lab before and after shipment to Europe, where it was used on 15 deep casts during a WOCE cruise in the Bay of Biscay.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